FIELD METHODS FOR THE CHLORINATION OF SMALL AMOUNTS OF WATER

By F. R. Georgia[1]

In the area occupied by the First Depot Division of the American Expeditionary Forces there were no developed water supplies. The French inhabitants depended entirely on wells dug in the chalk for their water. These wells, which were usually open at the top and otherwise improperly protected, were all polluted. Bacteriological examination of a large number of them failed to discover even one that yielded a water of potable quality.

Since the divisional area embraced some 1000 square kilometers and had to handle as many as 70,000 Americans at one time, it was necessary to chlorinate small amounts of water derived from these wells at a large number of points. Most of this chlorination was carried out in Lyster bags. The supervision and control of these bags will be discussed later.

As the work of the division became better organized it became advisable to establish camps for special purposes where troops were concentrated in barracks or tents. At these points it was necessary for the engineers to construct wells in order to obtain sufficient water. Some of these, as at the Prison Camp and the Venereal Labor Camp, were simple open dug wells from which water was drawn by buckets and chlorinated in Lyster bags. At others, notably Camp Hospital No. 26, the Classification Camp, the Special Training Battalion and the 116th Supply Train, pumps driven by gasoline engines were provided, together with storage tanks and limited distribution systems.

Where such improvements were made, it was thought advisable to attempt some form of continuous purification of the water as it was pumped. The amounts of water handled varied roughly from 2000 to 15,000 gallons per day, and it was at first thought improbable that such small supplies could be successfully and satisfactorily

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chlorinated without causing noticeable tastes in the water due to overdosage. The first of these supplies was developed at Camp Hospital No. 26, and since many of the patients objected to the tastes resulting from the chlorination of water in Lyster bags an attempt was made to chlorinate the entire supply as it was pumped.

For this purpose a home-made device, using chlorinated lime, was constructed. The original apparatus consisted merely of a barrel for storage of the stock solution of chlorinated lime, and a constant-level box fitted with a glass gauge and an orifice which consisted of a piece of soft rubber tubing with a screw pinchcock. It was necessary to calibrate the gauge in terms of the flow through this orifice. The solution was fed into a 1-inch galvanized iron pipe, which carried it down into the well to the end of the intake pipe of the pump. This apparatus consisted of parts *A* to *F* of the more complex apparatus shown in figure 1. The results obtained were highly satisfactory, as regards both bacterial removal and the absence of tastes in the treated water.

This led to the installation of a similar apparatus at the Special Training Battalion where similar results were obtained. Still another was installed at the 116th Supply Train, but no data are available, since the author left France immediately after it was set up. In addition to these home-made devices a Wallace-Tiernan liquid chlorine machine of the bubble meter, solution feed type was placed in use on the water supply of the Classification Camp.

Chlorination at Camp Hospital No. 26 was twice interrupted, due to the construction of new wells. The chlorinating device in use on this supply was finally modified to the more complex form described below, since this form allowed the suction line of the pump to be extended to other wells, without interrupting the chlorination, in case a larger supply became necessary.

But little trouble was experienced in the operation of any of these devices, once the proper strength of solution and rate of feed had been determined. It was necessary, however, to occasionally check up the men assigned to operate the machines. At one time the man operating the liquid chlorine machine allowed some chalky water to run through the apparatus and plug the valve where the chlorine water enters the suction line of the pump, with the result that all of the chlorine water went out the overflow. The trouble was located very shortly after a bad sample of water had been examined at the division laboratory. If the man had watched his apparatus he would have seen what was taking place.

At another time the man operating the machine at Camp Hospital No. 26 became ill and another man was placed in charge without being properly instructed in the operation of the chlorinating device. He operated the machine properly, except that he used only about one-fourth of the amount of chlorinated lime necessary to obtain proper results.

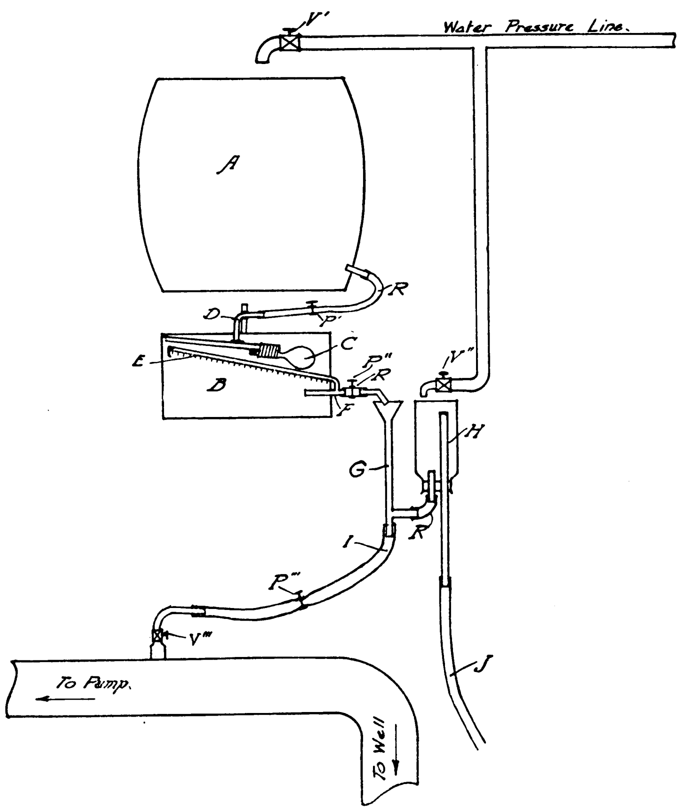

FIG. 1. APPARATUS FOR TREATING WATER WITH CHLORINATED LIME

A, Barrel for stock solution of chlorinated lime; *B*, constant level orifice box; *C*, constant level valve with glass float and rubber seat, hinged at end; *D*, glass tube which seats on *C; E*, gauge of glass for adjusting flow of solution; *F*, glass T-tube connecting with orifice; *G*, glass T-tube with funnel at top and connecting with water seal *H; H*, water seal of glass; *I*, heavy walled rubber tubing connecting *G* to suction pipe of pump; *J*, rubber tube for overflow from *H;* P^1, P^{11} P^{111}, screw pinch cocks; V^1, V^{11}, V^{111}, metal valves on pipe lines; *R*, connections of ordinary rubber tubing.

With the facilities available it was impossible to determine the amount of chlorine used with these special devices. Rather rough estimates would indicate, however, that the dosage was approximately one-half of a part per million of chlorine.

The device finally used at Camp Hospital No. 26 is shown in figure 1, and is followed by a description of the apparatus and its operation. Tables of some of the bacteriological results obtained are also included. The room temperature counts given are rather variable due to the fact that no room temperature incubator was available and the temperature in the laboratory was subject to rather large fluctuations.

In the operation of the chlorinating apparatus a stock solution of chlorinated lime, of proper strength, is made up in A, a water tap, V^1, being placed for convenience over the barrel. P^1 being open, this solution flows into B until C seats on D, stopping the flow. P^1 is closed only when the apparatus is not in use, being placed there to prevent the flooding of B in case the constant-level valve leaks slightly. The object of B is to maintain a constant level of solution and, therefore, a constant pressure on the orifice valve P^{11}.

P^{11} is opened until the gauge E indicates the proper flow of the solution. This gauge must be calibrated and the flow determined for different readings. If P^{111} and V^{111} are closed, the solution flowing through P^{11} will pass over into H and overflow through J. With the pump running, V^{111} is opened, after which P^{111} is opened *slowly* until the solution stops overflowing into J. Under these conditions, all of the solution flowing through P^{11}, plus a certain amount of air, will pass through V^{111} into the suction pipe of the pump. V^{11} is now opened allowing water to flow into H in sufficient quantity so that it overflows through J. Under these conditions, all of the solution passing through P^{11}, plus a small amount of water, passes through V^{111} into the suction pipe of the pump and all air is excluded.

The proper strength of solution and the amount of it to be used will vary with the capacity of the pump and the character of the water being treated, and must be determined for each case. The amount and strength of the solution to be used may, as a rule, be adjusted with a starch-iodide reagent but bacteriological control should be resorted to where possible.

After P^{111} has once been set it will not, as a rule, be necessary to change it unless the rate of the pump or the amount of solution used is changed.

TABLE 1

Bacteriological data on well at Camp Hospital No. 26

DATE	SOURCE	COLONIES PER CUBIC CENTIMETER ON AGAR		GAS PRODUCERS PER 100 CC. IN LACTOSE BOUILLON
		37.5°C.	Room temperature	
6/ 1/18	Pump*	8	140	14
6/ 1/18	Tap*	8	75	14
6/13/18	Pump*	43	175	50
6/26/18	Tap*	14	35	30
8/15/18	Pump*	65	40	60
8/15/18	Pump†	4	4	0
9/16/18	Pump‡	7	7	4
9/17/18	Pump‡	8	16	2
9/20/18	Tap‡	6	3	4
9/22/18	Tap‡	10	2	4
9/24/18	Pump‡	40	25	4
9/24/18	Tap‡	45	15	0
9/30/18	Tap§	5	3	0
10/ 8/18	Tap	1	1	0
11/ 4/18	Tap¶	1	15	4
11/ 6/18	Tap¶	0	5	0
11/ 7/18	Pump**	5	45	0
11/ 9/18	Tap	4	4	0
11/23/18	Tap	1	2	0
12/ 4/18	Tap††	25	6	4
12/10/18	Tap‡‡	7	120	100+
12/11/18	Tap§§	60	140	100+
12/12/18	Tap§§	20	60	100+
12/13/18	Tap§§	1	10	0
12/18/18	Tap	4	5	0

* First well before chlorination.

† First well after chlorination was started.

‡ Results on second well, which drained the first one. The same chlorinating device was used and the rate of feed readjusted.

§ Water pronounced potable.

¶ Old wells replaced by a third and larger one. A larger pump was installed and the chlorinating device modified to the form shown in figure 1.

** This sample taken, plated and 50 cc. inoculated into fermentation tubes within two minutes after the water was chlorinated. The results show the rapid action of chlorine on bacteria and especially on gas producers and other forms growing at 37.5°C., when dealing with clear, colorless waters, as in this case.

†† System contaminated by changes in pipe lines and storage tanks.

‡‡ New operator placed in charge of pump. Results due to his feeding less than one-fourth of the required amount of chlorinated lime.

§§ Results show return to normal when the proper amount of chlorinated lime was fed.

After the proper strength of solution has been determined and P^{111} has been adjusted, the following procedure should be followed in starting the apparatus:

Open P^1, adjust P^{11} to the proper flow, and open V^{111} before the pump is started. Start the pump and note whether the overflow at J stops. If it does open V^{11} until it starts to overflow again. If an overflow is obtained with V^{11} closed while the pump is running, P^{111} must be opened until this overflow stops.

TABLE 2

Bacteriological data on well at Special Training Battalion

DATE	SOURCE	COLONIES PER CUBIC CENTIMETER ON AGAR		GAS PRODUCERS PER 100 CC. IN LACTOSE BOUILLON
		37.5°C.	Room temperature	
8/23/18	Pump*	1,800	2,000	100+
9/17/18	Pump†	3	2	0
9/17/18	Pump	2	3	0
9/23/18	Pump	1	20	0
9/23/18	Tap‡	75	40	4
9/30/18	Tap§	1	1	0
10/ 2/18	Tap	0	1	0
10/ 8/18	Tap	0	0	0
10/12/18	Tap	1	0	0
10/27/18	Tap	1	2	0
11/ 1/18	Tap	2	3	0
11/ 8/18	Tap¶	300	450	90
11/12/18	Tap**	2	2	0
12/ 4/18	Tap	0	0	0
12/10/18	Tap	0	5	0
12/18/18	Pump	7	8	0
12/20/18	Pump	8	15	0

* Before chlorination.
† After chlorination.
‡ Storage tanks and pipes not flushed out.
§ Water pronounced potable.
¶ Engine broke down, system drained and one tank partly filled with unchlorinated water.
** New engine installed.

To shut down, stop the pump first and then close V^{111}, V^{11}, P^{11} and P^1 in the order named.

The Lyster bag is a canvas container lined with rubber, provided with five self-closing faucets near the bottom, a canvas cover to keep out dirt and a metal ring at the top from which it is supported by means of ropes. It has a capacity of about 36 gallons.

Sealed glass tubes containing 1 gram of chlorinated lime, having 30 per cent of available chlorine, were provided for the chlorination of these bags. One of these tubes was sufficient to impart a chlorine content of 2.2 parts per million to the water in one bag. Almost without exception this was enough to decidedly over-chlorinate the waters dealt with and to impart to them a rather pronounced taste. These tastes might have been eliminated by using smaller amounts

TABLE 3

Bacteriological data on well at Classification Camp

DATE	SOURCE	COLONIES PER CUBIC CENTIMETER ON AGAR		GAS PRODUCERS PER 100 CC. IN LACTOSE BOUILLON
		37.5°C.	Room temperature	
7/ 9/18	Pump*	6,000	20,000	100+
9/13/18	Pump†	0	0	0
9/13/18	Pump‡	0	0	0
9/13/18	Pump§	1	0	0
9/18/18	Pump	0	0	0
9/30/18	Pump¶	4	6	0
10/ 1/18	Tap**	13	12	20
10/ 2/18	Tap††	2	1	0
10/ 8/18	Tap‡‡	50	600	100+
10/10/18	Tap‡‡	400	3,000	100+
10/10/18	Pump§§	1	4	0
10/12/18	Tap	5	0	0
10/27/18	Tap	1	11	0
11/ 1/18	Tap	7	9	0
11/ 8/18	Pump	1	2	0
11/15/18	Pump	3	20	0
11/23/18	Pump	0	1	0
12/10/18	Tap	1	6	0
12/18/18	Tap	0	17	0

* Before chlorination.

† Chlorination rate, 60 bubbles per minute.

‡ Chlorination rate, 42 bubbles per minute.

§ Chlorination rate, 24 bubbles per minute. This rate was subsequently used.

¶ Two new wells connected with the old one. Water slightly turbid at first.

** Storage tanks and pipes not flushed out.

†† Water pronounced potable.

‡‡ Chlorine solution valve in the suction line of the pump clogged, excluding chlorine.

§§ Valve cleaned.

of chlorinated lime, but if this had been done much closer supervision of the bags would have been necessary.

TABLE 4

Bacteriological data on typical wells

DATE	SERIAL NUMBER	COLONIES PER CUBIC CENTIMETER ON AGAR		GAS PRODUCERS PER 100 CC. IN LACTOSE BOUILLON
		37.5°C.	Room temperature	
7/ 5/18	3092	2,250	500,000	100+
9/20/18	8814	100	150	12
9/20/18	8815	17	60	25
9/20/18	8816	23	65	100+
9/20/18	8817	65	750	100+
10/23/18	12864	750	2,000	100+
11/29/18	17013	10,000	50,000	100+
12/10/18	18783	30	270	100+

Since water was of necessity being chlorinated by a large number of individuals, who had no special training for work of this sort, it was thought best to issue definite rules for the care of Lyster bags that would cover all cases. A copy of these rules follows:

HEADQUARTERS FIRST DEPOT DIVISION

OFFICE OF THE DIVISION SURGEON, A. E. F.

October 5, 1918.

Memorandum:

CHLORINATION OF DRINKING WATER

Break a tube of calcium hypochlorite into a clean ordnance cup.

Moisten the powder with a few drops of water and mix into a smooth paste.

Now fill the cup with water to within 1 inch of the top and mix thoroughly by stirring with a clean spoon.

Add this solution to a Lyster bag filled with clean water, stir thoroughly, *and allow to stand thirty minutes before using.*

Broken or cracked tubes must not be used.

One-half hour after a bag has been chlorinated withdraw a cupful of water and add to it a few drops of starch-iodide reagent. If a blue color is obtained, the water is ready for use. If no color is obtained, the water must not be used and the process must be repeated.

Calcium hypochlorite tubes and the starch reagent can be obtained at the Laboratory, Camp Hospital No. 26, or from the Sanitary Squads.

O. G. BROWN,
Colonel, Medical Corps,
Division Surgeon.

500.

It was found necessary to use the starch-iodide or ortho-tolidine test for free chlorine after a bag had been chlorinated, for two reasons. In the first place, exceptional waters might require more chlorine than that contained in one tube of chlorinated lime. In the second case it was found that a large percentage of tubes reached France in a broken or cracked condition, with the contents spoiled. A crack might be hardly perceptible but usually resulted in the chlorinated

TABLE 5

Bacteriological data on Lyster bags

DATE	SERIAL NUMBER	COLONIES PER CUBIC CENTIMETER ON AGAR		GAS PRODUCERS PER 100 CC. IN LACTOSE BOUILLON
		37.5°C.	Room temperature	
8/10/18	5397*	8,400	20,000	100+
8/22/18	6536*	30,000	50,000	100+
8/22/18	6537	1	2	0
8/22/18	6538	1	8	0
8/23/18	6686	1	2	0
8/23/18	6687*	2	40	100+
8/23/18	6688	1	2	0
8/31/18	7134	2	2	0
8/31/18	7136	2	1	0
8/31/18	7137	4	2	0
9/13/18	8217*	300	1,500	100+
9/14/18	8248†	25	3,000	0
9/20/18	8812*	3,000	5,000	12
9/20/18	8813*	6	10	12
9/26/18	9308*	320	650	25
9/30/18	9643*	850	1,250	100+
9/30/18	9646*	30	5	100+
9/30/18	9647*	110	75	100+
10/13/18	11,139	1	2	0

* Not chlorinated, chlorinated with spoiled tubes, or recontaminated.

† Sample taken more than 24 hours after chlorination.

lime in the tube becoming pasty. Unless properly instructed, men were liable to use such tubes and it was for this reason chiefly that a test for free chlorine was required for each bag before it was used.

In addition to the above precautions, occasional bacteriological samples were examined at the division laboratory.

A separate record was kept for each Lyster bag, from which it was possible to fix responsibility for the proper care of these bags. A copy of the blank form used follows:

RECORD OF WATER IN LYSTER BAG

FIRST DEPOT DIVISION

DATE	HOUR OF ADDING HYPOCHLORITE	BY WHOM CHLORINATED	HOUR OF TESTING	BY WHOM TESTED	RESULT OF TEST
....	....	....	....	....	....
....	....	....	....	....	....
....	....	....	....	....	....
....	....	....	....	....	....

All water for drinking purposes was required to be chlorinated and all troops were ordered to drink only such water.

Stringent regulations of this sort were necessary, for it seems to be a characteristic of human nature that people will not believe in dangers that they cannot see. Moreover man is a lazy animal and usually has to be compelled to do things.

One rather striking illustration of the value of chlorination was obtained from a unit, the medical officer of which did not believe in the necessity for this precaution. In this unit Lyster bags were used merely as containers for water of bad quality with the result that a high percentage of the command suffered from diarrhoea. As soon as this condition was discovered steps were taken to compel the chlorination of the water used by the unit with the result that diarrhoea almost disappeared.

Tables 4 and 5 give some of the bacteriological results from wells in the area and on Lyster bags.